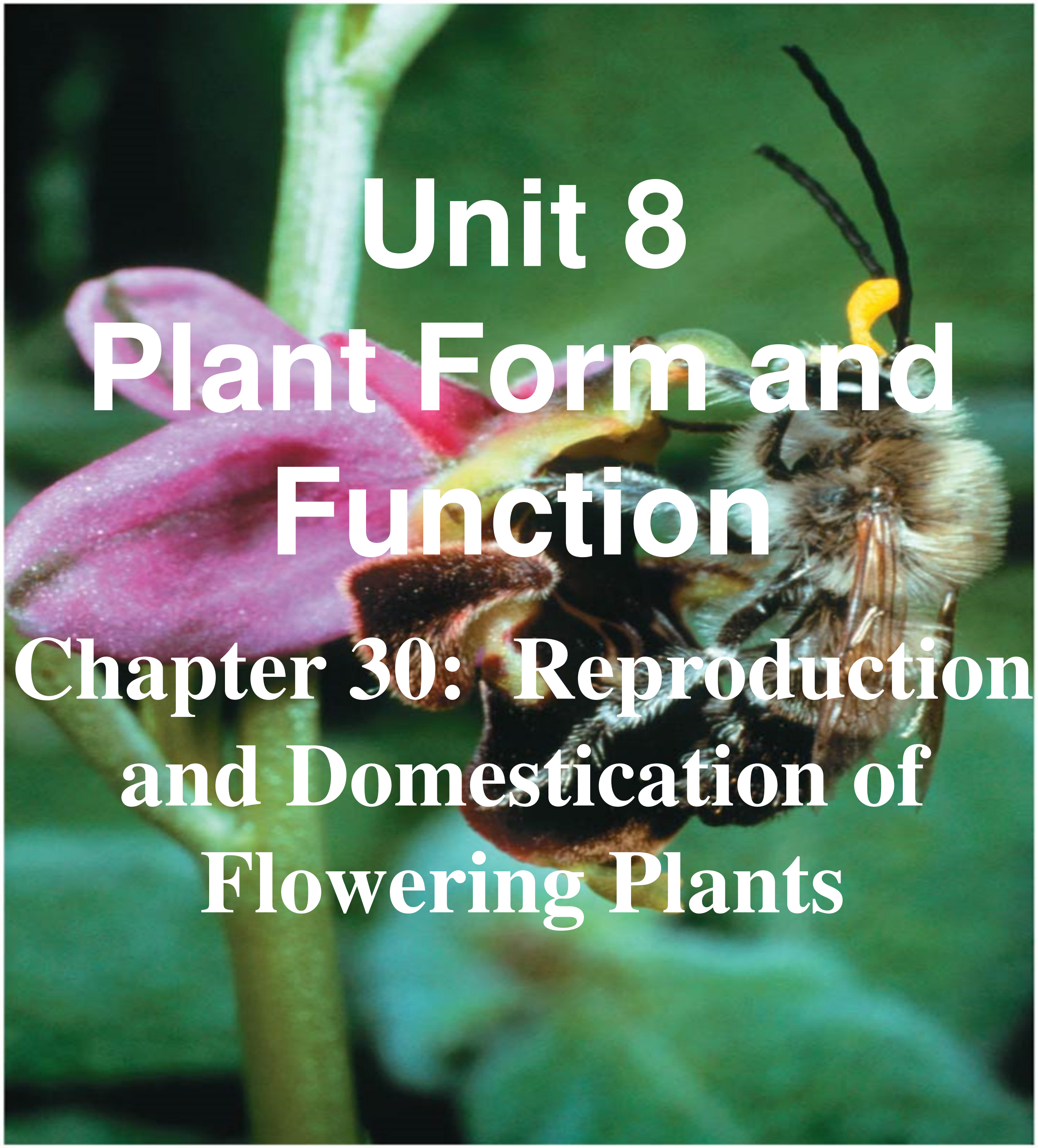


Unit 8
Plant Form and Function

Chapter 30: Reproduction and Domestication of Flowering Plants

Overview: Flowers of Deceit

- Angiosperms can reproduce sexually and asexually
- Insects help angiosperms to reproduce sexually with distant members of their own species
- Many angiosperms lure insects with nectar or pollen
  - Both plant and pollinator benefit
- Participation in mutually beneficial relationships with other organisms is common in the plant kingdom
  - Humans and crops
- Angiosperms are the most important group of plants in terrestrial ecosystems and in agriculture

Concept 30.1: Flowers, double fertilization, and fruits are unique features of the angiosperm life cycle

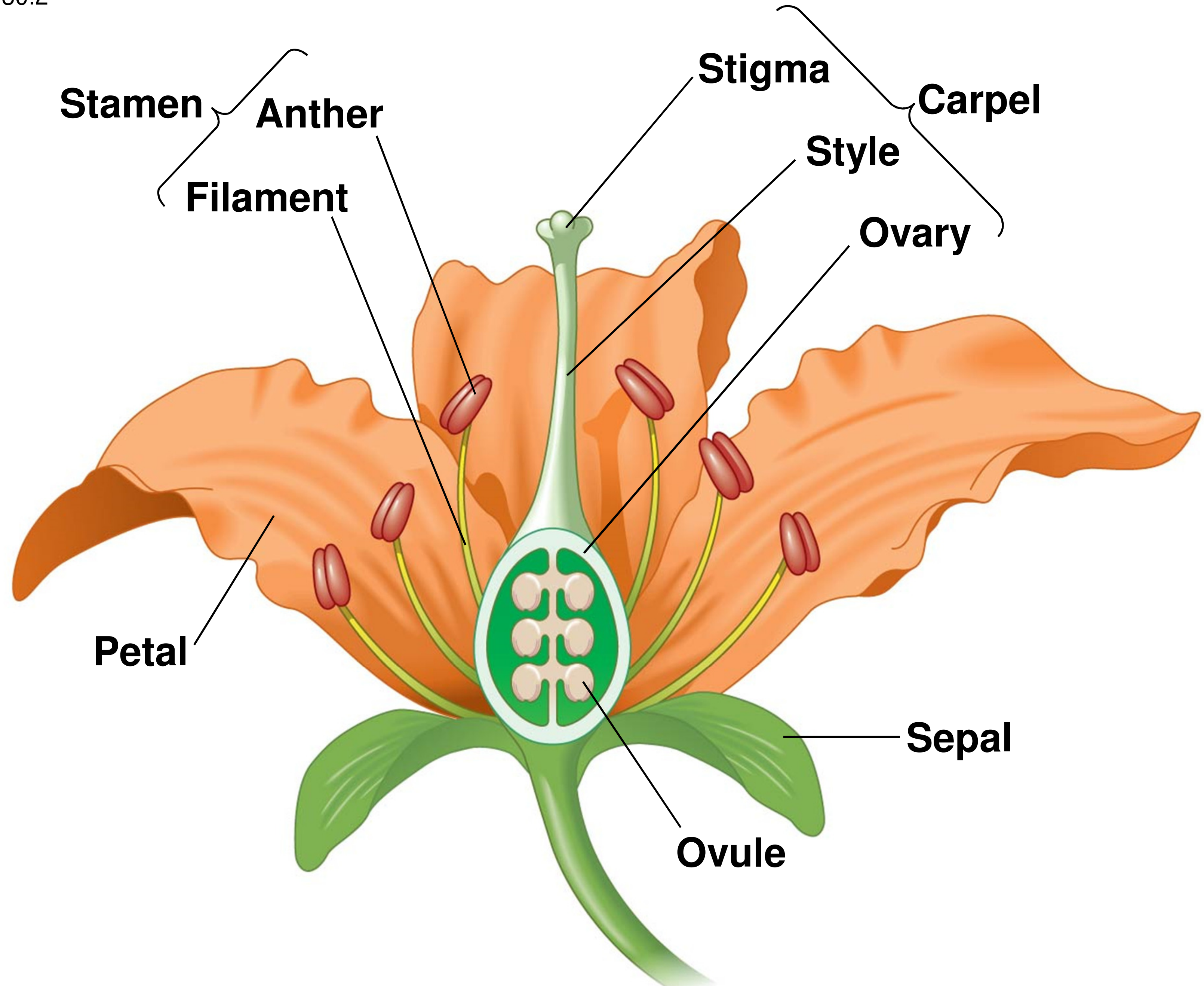
- Plant life cycles are characterized by the alternation between a multicellular haploid (*n*) generation and a multicellular diploid (2*n*) generation
- Diploid sporophytes (2*n*) produce spores (*n*) by meiosis
  - These grow and divide into multicellular haploid gametophytes (*n*)
- Gametophytes produce haploid gametes (*n*) by mitosis
  - **Fertilization** of gametes produces a sporophyte

- In angiosperms, the sporophyte is the dominant generation, the large plant that we see
- The gametophytes are reduced in size and depend on the sporophyte for nutrients
- The angiosperm life cycle is characterized by "three Fs"
  - Flowers
  - Double Fertilization
  - Fruits

Flower Structure and Function

- Flowers are the reproductive shoots of the angiosperm sporophyte
  - They attach to a part of the stem called the **receptacle**
- Flowers are determinate shoots
  - They cease growing after flower and fruit are formed
- Flowers consist of four floral organs: **carpels**, **stamens**, **petals**, and **sepals**
  - Carpels (female parts) and stamens (male parts) are reproductive organs
  - Sepals and petals are sterile

Figure 30.2


Stamen
Anther
Filament
Stigma
Carpel
Style
Ovary
Petal
Sepal
Ovule

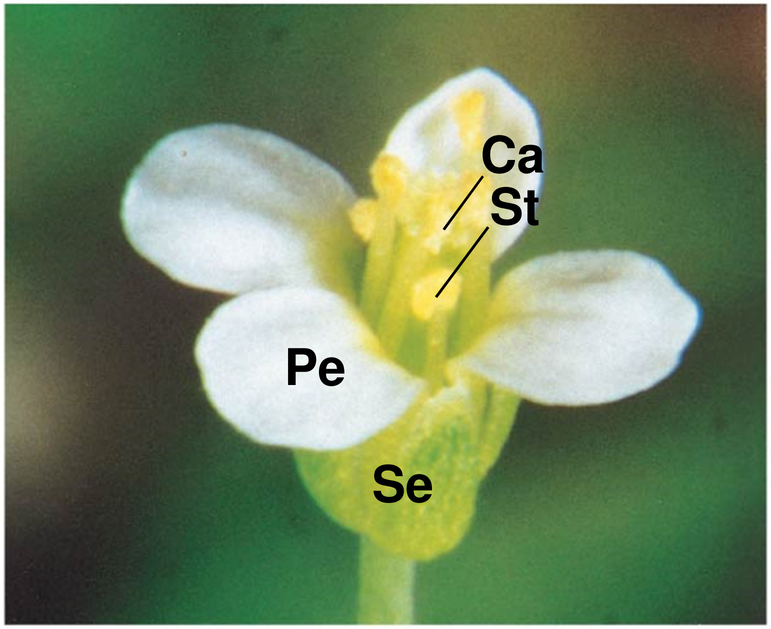
- A single carpel or group of fused carpels is called a **pistil**
  - A carpel has a long **style** with a sticky **stigma** on which pollen may land
  - At the base of the style is an **ovary** containing one or more **ovules**
- A stamen consists of a *filament* topped by an **anther** with pollen sacs that produce pollen
- Petals are typically brightly colored to attract pollinators
- Sepals enclose and protect unopened floral buds
  - Resemble leaves

- **Complete flowers** contain all four floral organs
- **Incomplete flowers** lack one or more floral organs, for example, stamens or carpels
- Clusters of flowers are called **inflorescences**
  - Ex: Daisy

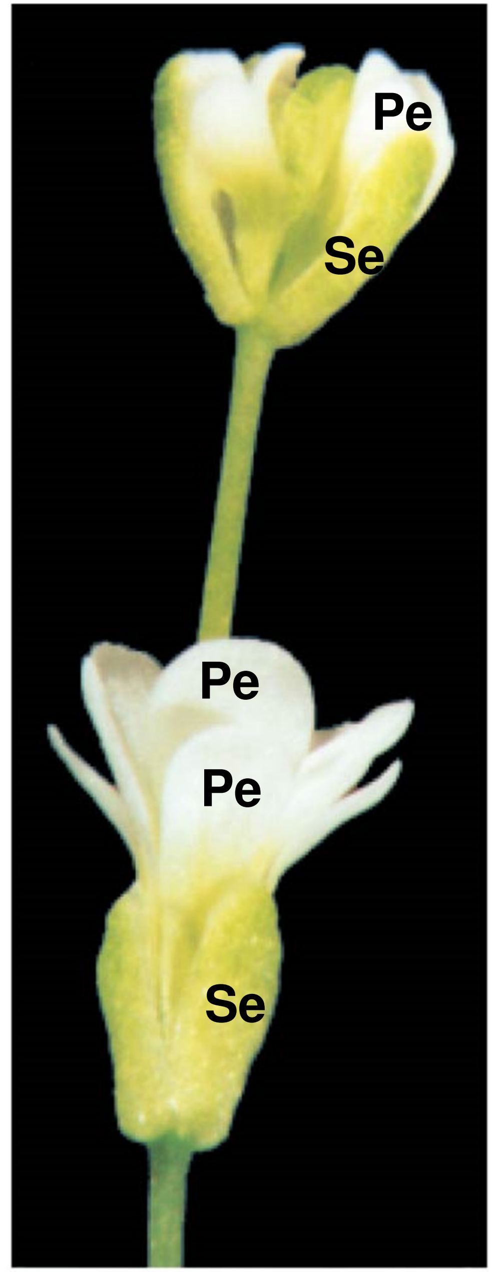
Flower Formation

- Flowers of a given plant species typically appear synchronously, promoting outbreeding
- The transition from vegetative to reproductive growth is triggered by environmental cues and internal signals
  - *Floral meristem*
- Floral organization is regulated by the products of floral identity genes
- Mutations in these genes cause abnormal floral development

Figure 30.3

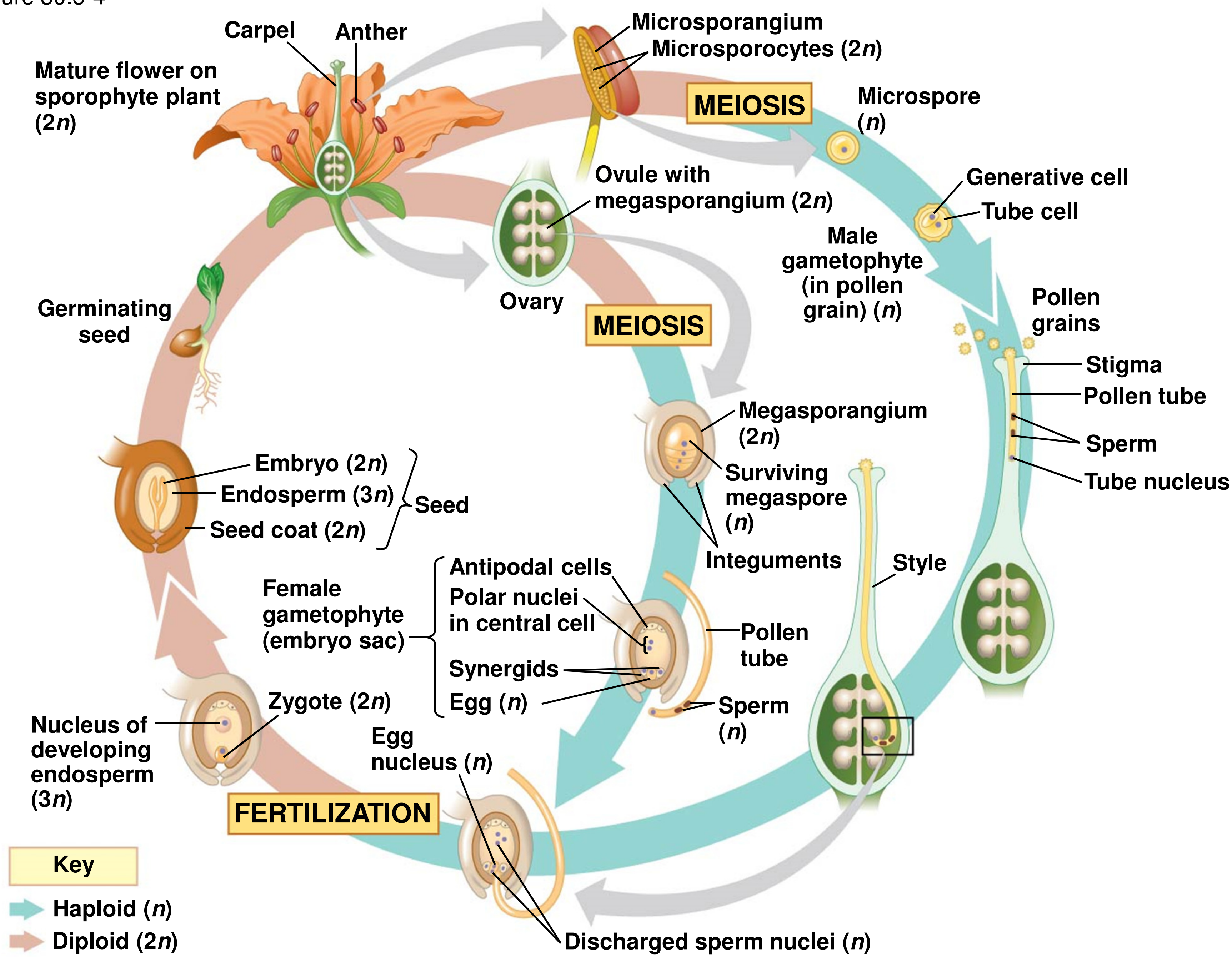


Normal *Arabidopsis* flower



Abnormal *Arabidopsis* flower

Figure 30.5-4



Carpel
Anther
Mature flower on sporophyte plant (2n)
Microsporangium
Microsporocytes (2n)
MEIOSIS
Microspore (n)
Ovule with megasporangium (2n)
Generative cell
Tube cell
Male gametophyte (in pollen grain) (n)
Ovary
MEIOSIS
Germinating seed
Pollen grains
Stigma
Pollen tube
Megasporangium (2n)
Sperm
Surviving megaspore (n)
Tube nucleus
Embryo (2n)
Endosperm (3n)
Seed coat (2n)
Seed
Integuments
Style
Antipodal cells
Female gametophyte (embryo sac)
Polar nuclei in central cell
Pollen tube
Synergids
Egg (n)
Sperm (n)
Zygote (2n)
Nucleus of developing endosperm (3n)
Egg nucleus (n)
FERTILIZATION
Key
Haploid (n)
Diploid (2n)
Discharged sperm nuclei (n)

Development of Female Gametophytes (Embryo Sacs)

- The **embryo sac**, or female gametophyte, develops within the ovule
- Within an ovule, two integuments surround a megasporangium
- One cell in the megasporangium undergoes meiosis, producing four haploid **megaspores**
  - Only one megaspore survives
- The megaspore divides, producing a large cell with eight haploid nuclei

Development of Male Gametophytes in Pollen Grains

- Each anther produces 4 microsporangia (pollen sacs)
- Pollen develops from haploid **microspores** within the microsporangia of anthers
- Each microspore undergoes mitosis to produce a haploid gametophyte consisting of only two cells:
  - The generative cell and the tube cell
- A **pollen grain** consists of the two-celled male gametophyte and the spore wall
- If pollination succeeds, a pollen grain produces a **pollen tube** that grows down into the ovary and discharges two sperm cells near the embryo sac

Pollination

- In angiosperms, **pollination** is the transfer of pollen from an anther to a stigma
  - Pollination can be by wind, water, or animals
  - Most angiosperms depend on insects, birds, or other animal pollinators
- Floral adaptations to attract bees include
  - Production of nectar
  - Sweet fragrance
  - Brightly colored petals
  - "Nectar guides"

Figure 30.6a

Abiotic pollination by wind

Hazel staminate flower (stamens only)

Hazel carpellate flower (carpels only)

Pollination by insects

Common dandelion under normal light

Common dandelion under ultraviolet light

Figure 30.6b

Pollination by bats or birds

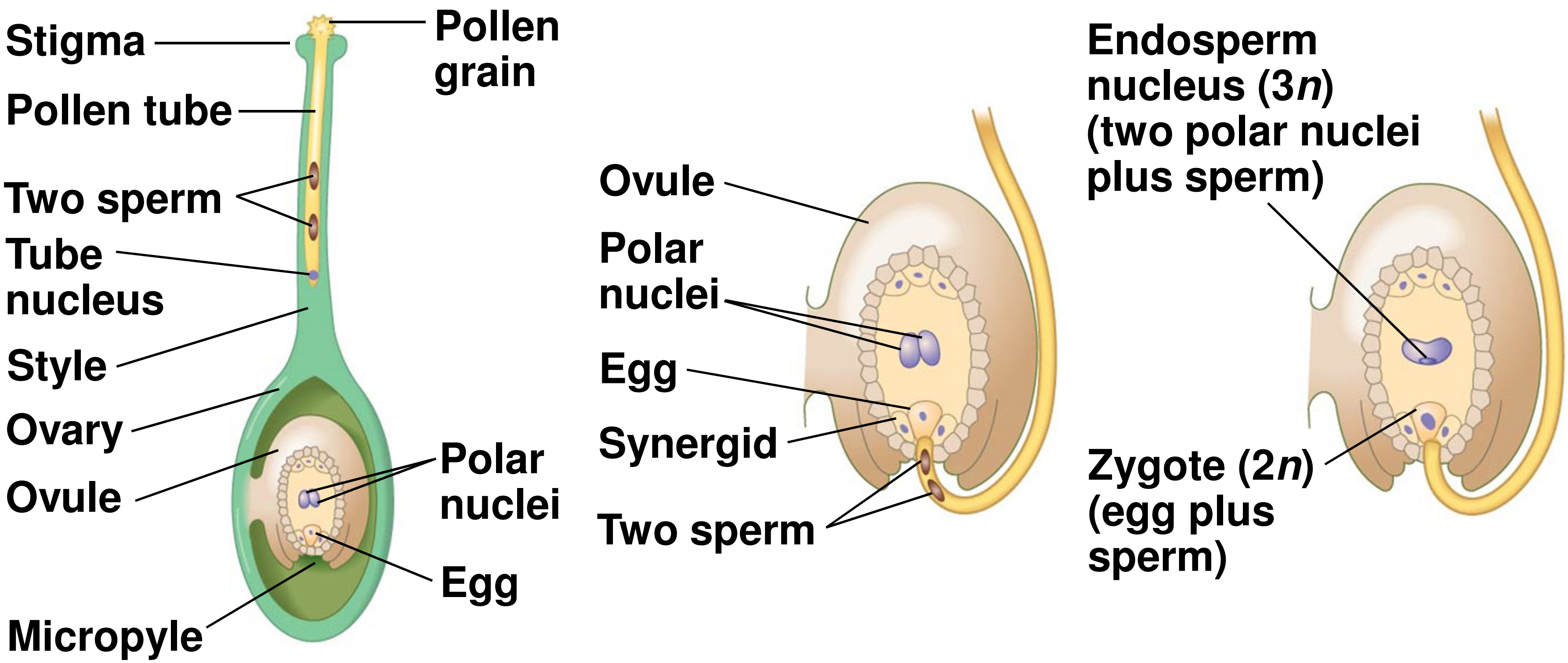
Long-nosed bat feeding on cactus flower at night

Hummingbird drinking nectar of columbine flower

Double Fertilization

- After landing on a receptive stigma, a pollen grain produces a pollen tube that extends between the cells of the style toward the ovary
- **Double fertilization** results from the discharge of two sperm from the pollen tube into the embryo sac
  - One sperm fertilizes the egg
  - The other combines with the polar nuclei
    - Gives rise to the triploid food-storing **endosperm** (3*n*)
- Double fertilization ensures that endosperm develops only in ovules where the egg has been fertilized

Figure 30.7-3


Stigma
Pollen grain
Pollen tube
Two sperm
Tube nucleus
Style
Ovary
Ovule
Polar nuclei
Egg
Micropyle
Ovule
Polar nuclei
Egg
Synergid
Two sperm
Endosperm nucleus (3n) (two polar nuclei plus sperm)
Zygote (2n) (egg plus sperm)

Seed Development, Form, and Function

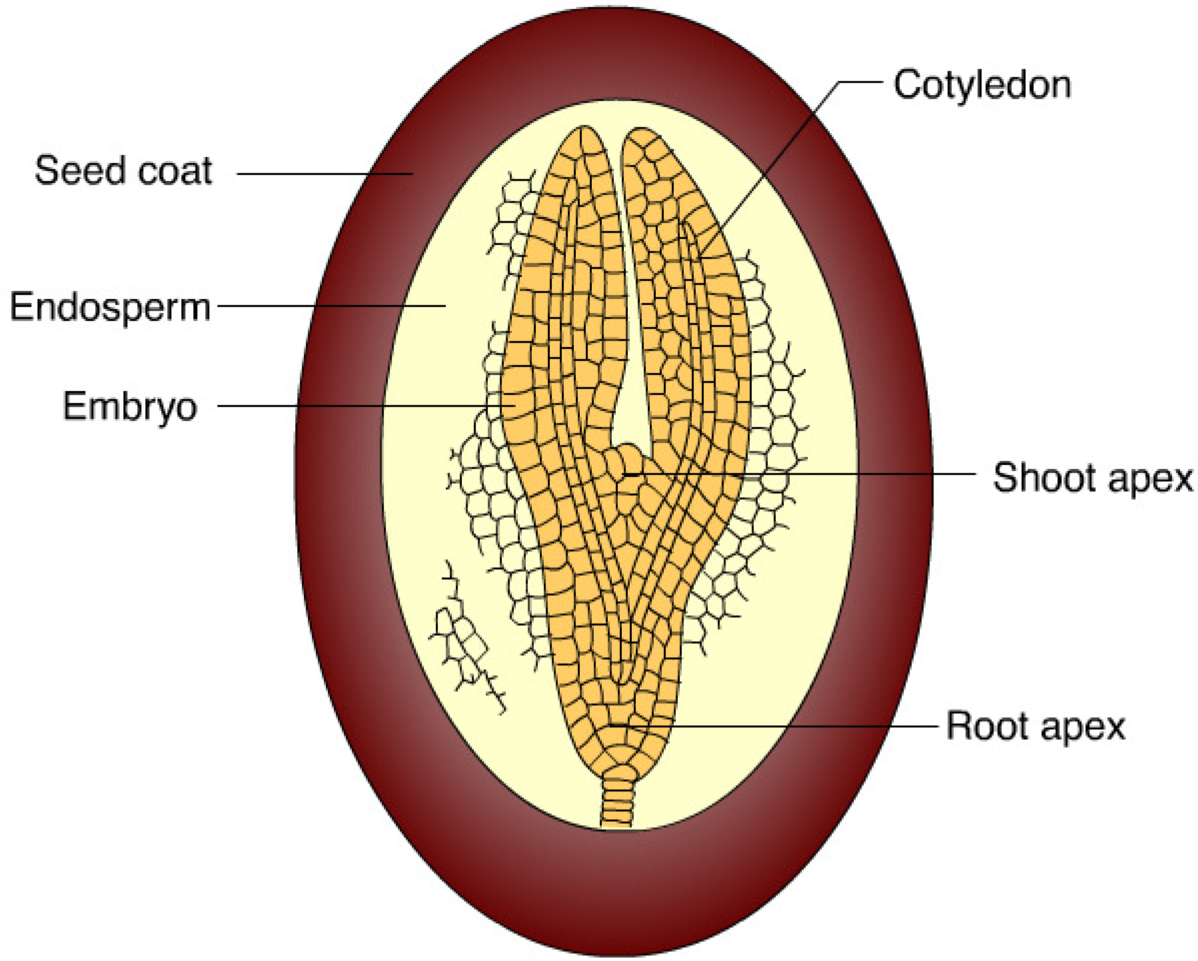
- After double fertilization, each ovule develops into a seed
- The ovary develops into a fruit enclosing the seed(s)
- Initially, carbohydrates and other nutrients are stored in the endosperm
  - Later the cotyledons (seed leaves) take over this function

Endosperm Development

- Endosperm development usually precedes embryo development
- In most monocots and some eudicots, endosperm stores nutrients that can be used by the seedling
- In other eudicots, the food reserves of the endosperm are exported to the cotyledons

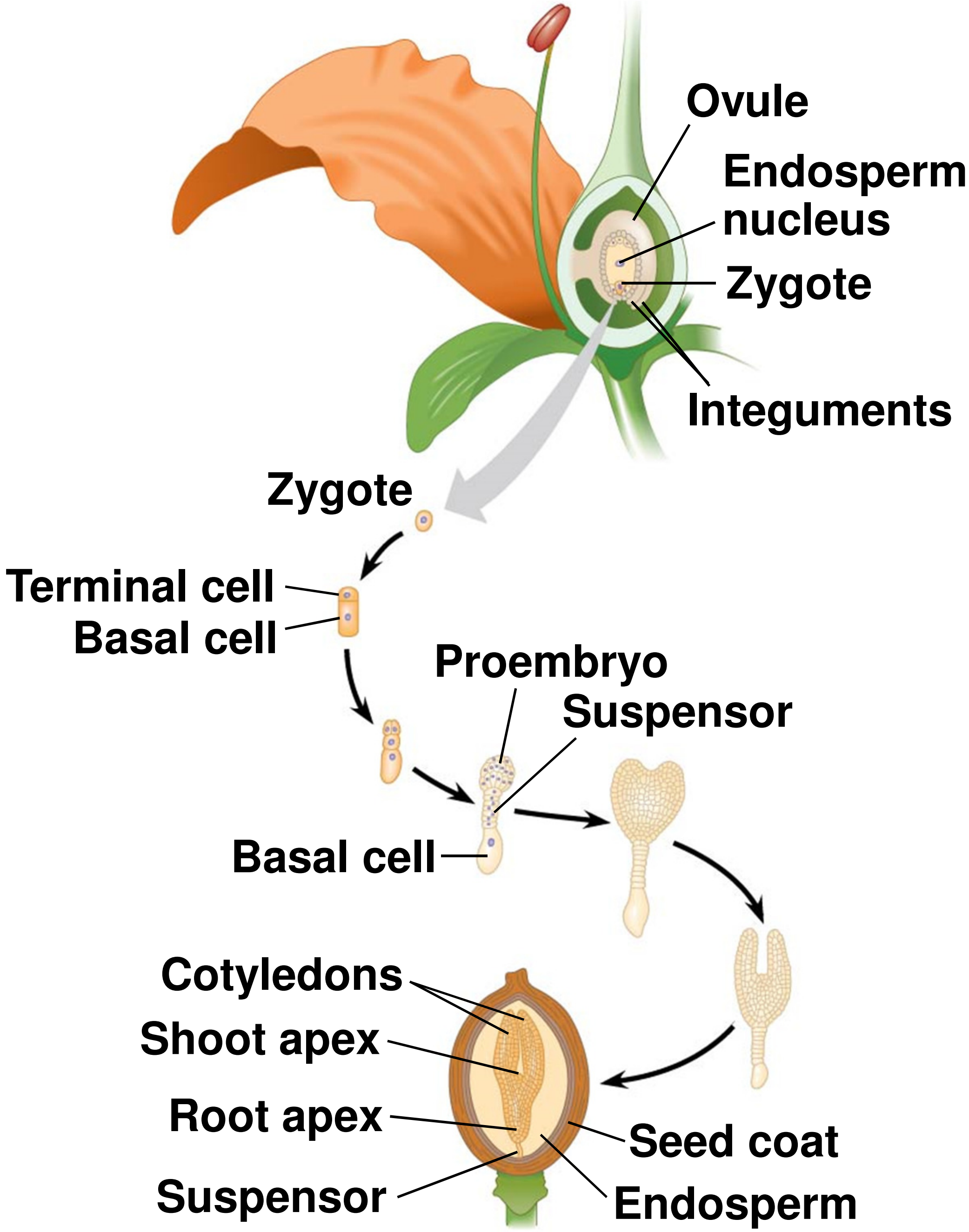
Embryo Development

- The first mitotic division of the zygote splits the fertilized egg into a basal cell and a terminal cell
  - The basal cell produces a multicellular *suspensor*
    - Anchors the embryo to the parent plant
  - The terminal cell gives rise to most of the embryo
- The cotyledons form and the embryo elongates



Animation: Seed Development
Right click slide / Select play

Figure 30.8


Ovule
Endosperm nucleus
Zygote
Integuments
Zygote
Terminal cell
Basal cell
Proembryo
Suspensor
Basal cell
Cotyledons
Shoot apex
Root apex
Suspensor
Seed coat
Endosperm

Structure of the Mature Seed

- The embryo and its food supply are enclosed by a hard, protective **seed coat**
- The seed enters a state of **dormancy**
  - Stops growing and slows metabolism

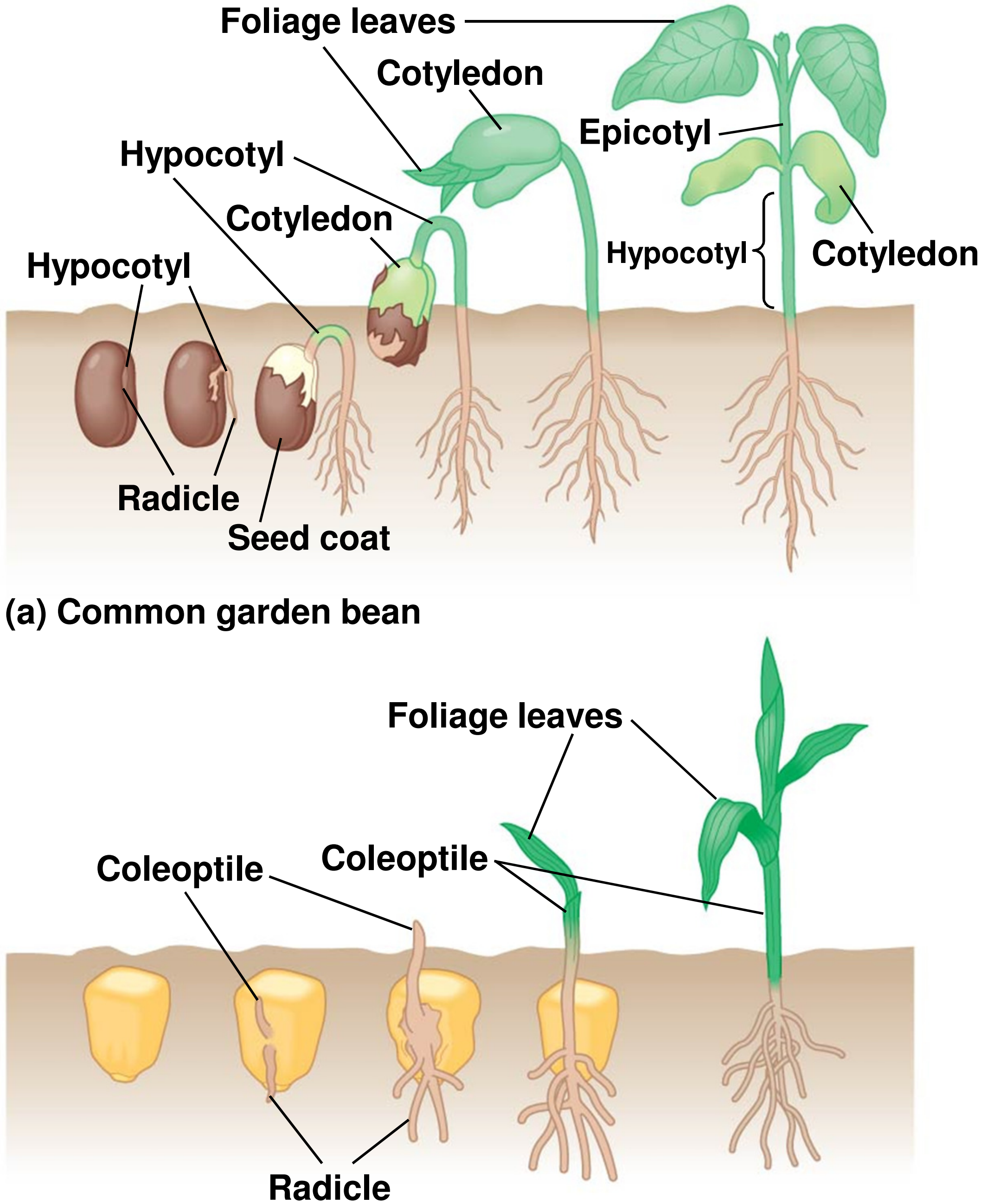
Seed Dormancy: An Adaptation for Tough Times

- Seed dormancy increases the chances that germination will occur at a time and place most advantageous to the seedling
- The breaking of seed dormancy often requires environmental cues
  - Temperature or lighting changes
  - Substantial rainfall (desert species)
  - Heat or smoke (where fires are common)
  - Chemical attacks as they pass through animal’s digestive tract

Seed Germination and Seedling Development

- Germination depends on **imbibition**
  - Uptake of water due to low water potential of the dry seed
- The radicle (embryonic root) emerges first
- Next, the shoot tip breaks through the soil surface

Figure 30.10



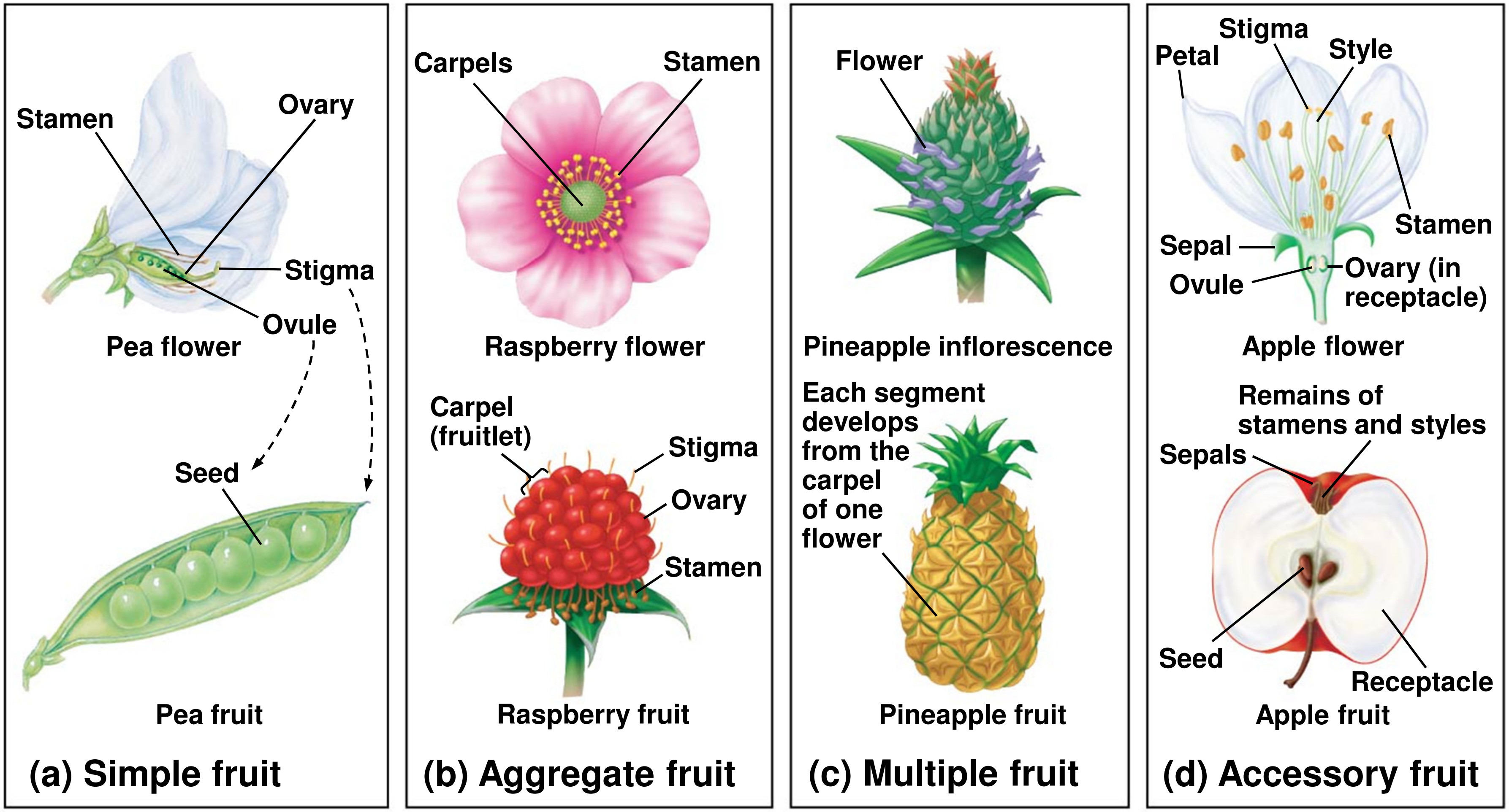
(a) Common garden bean

(b) Maize

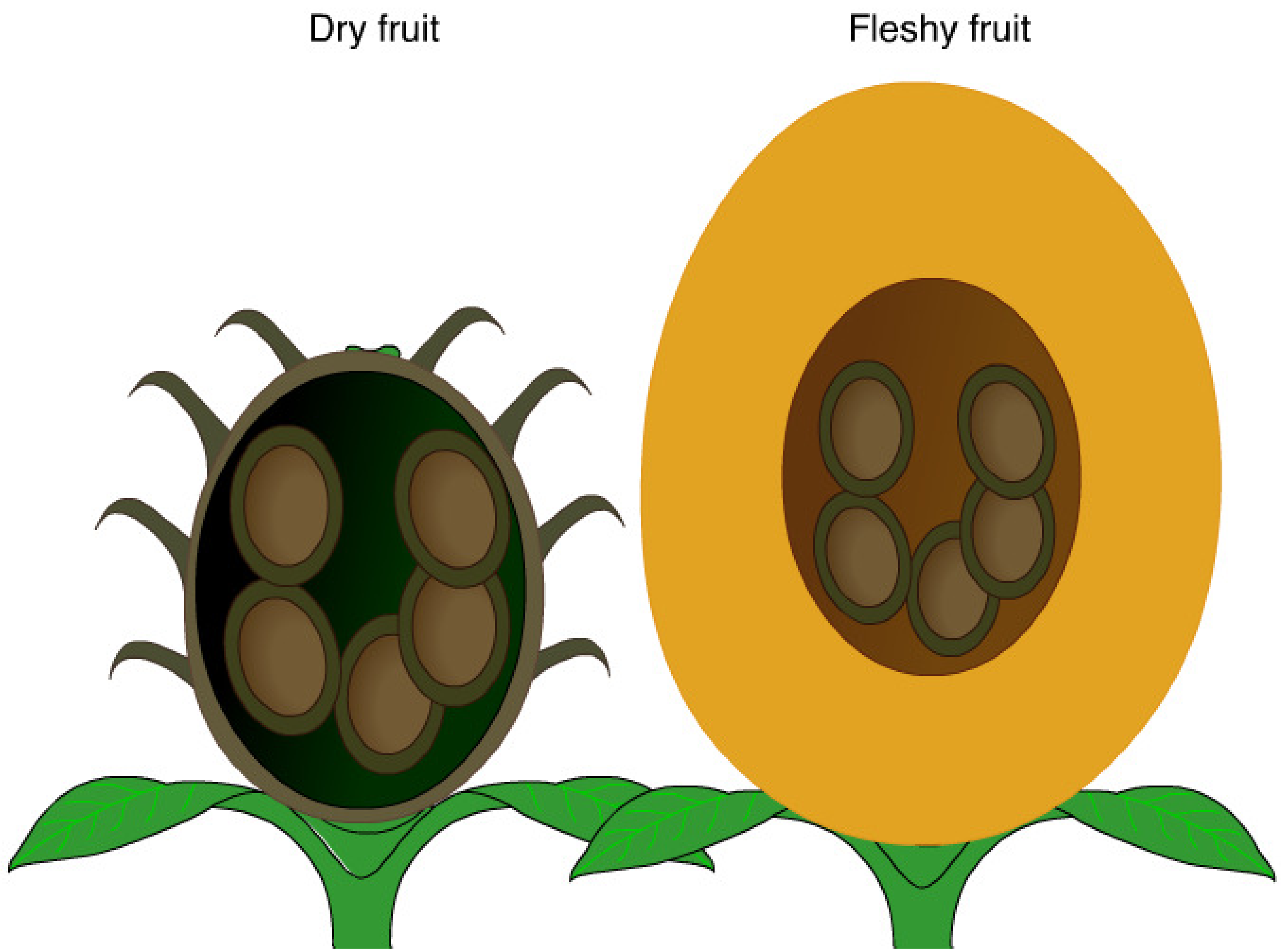
Fruit Form and Function

- Fertilization triggers hormonal changes that cause the ovary to develop into a **fruit**
  - Protects the enclosed seeds and aids in seed dispersal by wind or animals
- Fruits can be classified by their developmental origins
  - **Simple**, from a single or several fused carpels
  - **Aggregate**, from a single flower with multiple separate carpels
  - **Multiple**, from a group of flowers called an inflorescence
- An **accessory fruit** contains other floral parts in addition to ovaries

Figure 30.11



Stamen
Ovary
Stigma
Ovule
Pea flower
Seed
Pea fruit
(a) Simple fruit
Carpels
Stamen
Raspberry flower
Carpel (fruitlet)
Stigma
Ovary
Stamen
Raspberry fruit
(b) Aggregate fruit
Flower
Pineapple inflorescence
Each segment develops from the carpel of one flower
Pineapple fruit
(c) Multiple fruit
Stigma
Petal
Style
Stamen
Sepal
Ovule
Ovary (in receptacle)
Apple flower
Remains of stamens and styles
Sepals
Seed
Receptacle
Apple fruit
(d) Accessory fruit



Animation: Fruit Development

Right click slide / Select play

- Fruit dispersal mechanisms include
  - Water
    - Occurs in buoyant seeds and fruits like coconut, which can survive for long periods at sea
  - Wind
    - Occurs in seeds and fruits that have adaptations such as parachute or winglike structures
  - Animals
    - Occurs in seeds and fruits that are edible or adapted to attach to an animal’s skin or fur

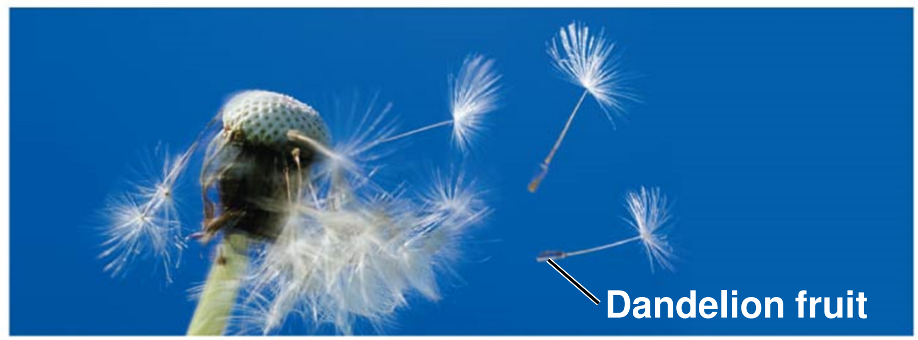
Figure 30.12a

Dispersal by water

Coconut seed embryo, endosperm, and endocarp inside buoyant husk

Dispersal by wind

Giant seed of the tropical Asian climbing gourd *Alsomitra macrocarpa*



Dandelion “seeds” (actually one-seeded fruits)

Winged fruit of a maple

Tumbleweed

Figure 30.12b

Dispersal by animals

Fruit of puncture vine (*Tribulus terrestris*)

Squirrel hoarding seeds or fruits underground

Seeds dispersed in black bear feces

Ant carrying seed with attached "food body"

Concept 30.2: Flowering plants reproduce sexually, asexually, or both

- Many angiosperm species reproduce both asexually and sexually
- Sexual reproduction results in offspring that are genetically different from their parents
- **Asexual reproduction** results in a clone of genetically identical organisms

Mechanisms of Asexual Reproduction

- **Fragmentation** is the separation of a parent plant into parts that develop into whole plants
  - A very common type of asexual reproduction
- In some species, a parent plant's root system gives rise to adventitious shoots that become separate shoot systems
- **Apomixis** is the asexual production of seeds from a diploid cell
  - Plants clone themselves by an asexual process
  - But still have the advantage of seed dispersal

Advantages and Disadvantages of Asexual Versus Sexual Reproduction

- Asexual reproduction is also called **vegetative reproduction**
- Asexual reproduction can be beneficial to a successful plant in a stable environment
  - No need for a pollinator
  - Allows plant to pass on all of its genetic legacy intact
  - Can quickly produce multiple clones
  - Generally stronger
  - Flowering and fruiting are “expensive” in terms of resources
- However, a clone of plants is vulnerable to local extinction if there is an environmental change

- Sexual reproduction generates genetic variation that makes evolutionary adaptation possible
  - Numerous seeds compensate for odds against individual survival
  - Seeds facilitate dispersal to more distant locations
  - Seed dormancy allows growth to be suspended until environmental conditions become favorable
- However, only a fraction of seedlings survive
- Some flowers can self-fertilize to ensure that every ovule will develop into a seed
- Many species have evolved mechanisms to prevent “selfing”

Mechanisms That Prevent Self-Fertilization

- Many angiosperms have mechanisms that make it difficult or impossible for a flower to self-fertilize
  - **Dioecious** species have staminate and carpellate flowers on separate plants
  - Others have stamens and carpels that mature at different times or are arranged to prevent selfing
  - The most common is **self-incompatibility**
    - A plant’s ability to reject its own pollen

Figure 30.14

(a) Staminate flowers (left) and carpellate flowers (right) of a dioecious species

Thrum flower **Pin flower**

(b) Thrum and pin flowers

Totipotency, Vegetative Reproduction, and Tissue Culture

- **Totipotent** cells are able to asexually generate a clone of the original organism through cell division
- When vegetative reproduction is induced by humans it is called **vegetative propagation**
  - Many kinds of plants are asexually reproduced from plant fragments called cuttings
- A **callus** is a mass of dividing undifferentiated cells that forms where a stem is cut and produces adventitious roots

- A twig or bud can be grafted onto a plant of a closely related species or variety
  - Makes it possible to combine the best qualities of different species or varieties into a single plant
- The **stock** provides the root system
- The **scion** is grafted onto the stock

- Plant tissue culture facilitates genetic engineering and the elimination of viruses

Concept 30.3: People modify crops through breeding and genetic engineering

- People have intervened in the reproduction and genetic makeup of plants for thousands of years
- Hybridization is common in nature and has been used by breeders to introduce new genes
  - Maize, a product of artificial selection, is unable to persist in nature

Plant Breeding

- Mutations can arise spontaneously or can be induced by breeders
- Plants with beneficial mutations are used in breeding experiments
- Desirable traits can be introduced by hybridizing wild species with domestic varieties within the same species or genus

Plant Biotechnology and Genetic Engineering

- Plant biotechnology has two meanings
  - In a general sense, it refers to innovations in the use of plants to make useful products
  - In a specific sense, it refers to use of genetically modified (GM) organisms in agriculture and industry
- Modern plant biotechnology is not limited to transfer of genes between closely related species or genera
- **Transgenic** organisms are genetically modified to express a gene from another species

Reducing World Hunger and Malnutrition

- Genetically modified plants may increase the quality and quantity of food worldwide
- Transgenic crops have been developed that
  - Produce proteins to defend them against insect pests
  - Tolerate herbicides
  - Resist specific diseases
  - Have improved nutritional quality

Reducing Fossil Fuel Dependency

- Fossil fuels, especially oil, produce pollution and are being depleted
- **Biofuels** are derived from living **biomass**
  - The total mass of organic matter in a group of organisms
- Biofuels would reduce the net emission of CO_2, a greenhouse gas
  - Even though they release CO_2 when burned, biofuel crops reabsorb CO_2 by photosynthesis

The Debate over Plant Biotechnology

- Some biologists are concerned about releasing GM organisms (GMOs) into the environment
- The concern originates from the unstoppable nature of the "experiment"

Issues of Human Health

- One concern is that genetic engineering may transfer allergens from a gene source to a plant used for food
- Some GMOs have health benefits

Possible Effects on Nontarget Organisms

- Many ecologists are concerned that the growing of GM crops might have unforeseen effects on nontarget organisms

Addressing the Problem of Transgene Escape

- Perhaps the most serious concern is the possibility of introduced genes escaping into related weeds through crop-to-weed hybridization
- This could result in “superweeds” that would be resistant to many herbicides

- Efforts are under way to prevent this by introducing
  - Male sterility
  - Apomixis
  - Transgenes into chloroplast DNA (not transferred by pollen)
  - Strict self-pollination